

NASA SP 427

# HIGH ALTITUDE PERSPECTIVE



# HIGH ALTITUDE PERSPECTIVE

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**National Aeronautics and Space Administration**

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# FOREWORD

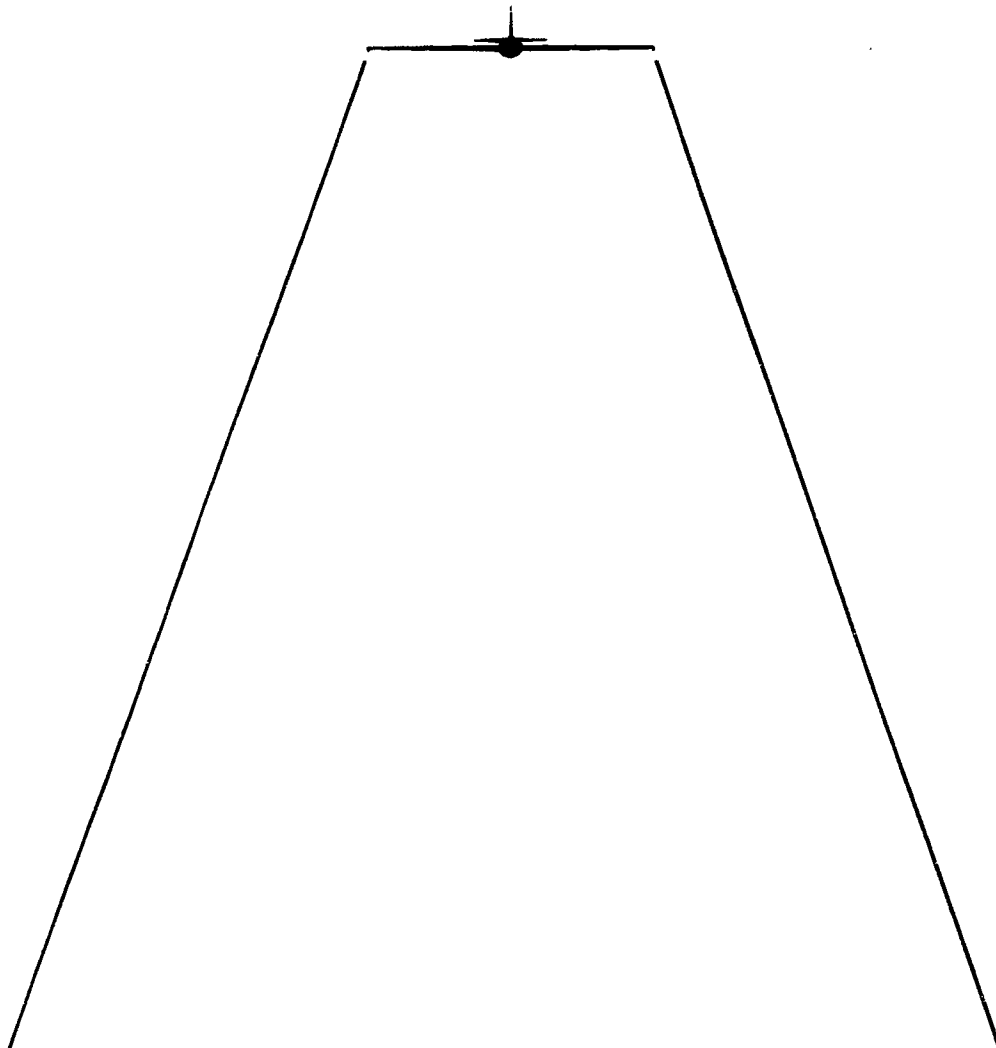
From the prehistoric hunter who scaled a peak to scout the lay of the land to the astronaut photographing the Earth's hemisphere from 75 000 kilometers, man has always especially prized the view from above. It is the richest of all perspectives, densely packed with information, closest to that uniquely human concept, the map. During two decades of space exploration, orbital imagery of our planet has been revealed as one of the most exciting and rewarding benefits of space.

Yet we should never forget the value of aircraft as platforms for our sensors and scientific instruments. So useful is aerial photography at low and moderate altitudes that it has created an industry that serves countless purposes. The unusual aircraft that is the subject of this descriptive booklet, flying at altitudes above those generally attained in conventional aerial photography, has an enlarged scope. It can scan shorelines, measure water levels, help fight forest fires, collect mapping data, assess flood damage, and sample the stratosphere. Over the oceans it can make sensitive measurements of water color and current; over land it can provide a form of "ground truth" that is valuable in calibrating the rich store of information from our satellites. Because it can do these things so well, it deserves attention for the service it is providing.

January 1978

Anthony J. Calio,  
Associate Administrator  
for Space and Terrestrial Applications

# INTRODUCTION



This publication was prepared in response to many requests for information on the availability of the U-2 aircraft managed by Ames research Center, for use in high-altitude investigations that cannot be performed by the private sector. Prospective users of the U-2 will find helpful information about the aircraft, the sensors it provides or can accommodate, its potential applications, and associated data-handling provisions. In an era of growing awareness of the Earth's environmental fragility and limited natural resources, aircraft and spacecraft have proved to be excellent platforms for remote and in situ sensing devices. Scientists and engineers at Ames Research Center have managed aircraft-supported research missions since 1964. Experience has been gained with a variety of aircraft – a Convair 990 airborne research laboratory, a C-141 airborne infrared observatory, Learjet aircraft, and more recently, two high-altitude U-2's.

The U-2 and Convair 990 aircraft are available on a cost-reimbursable basis for research or experimental programs in such areas as Earth resources inventories, remote sensing data interpretation, electronic sensor research and development, satellite investigative support, stratospheric gas studies, and astronomy and astrophysics.

# TYPICAL U-2 SUPPORT ACTIVITIES

## **WATER RESOURCES**

U-2 photos have helped the California Department of Water Resources measure water levels in rivers and reservoirs, especially during drought years. High-altitude photos of San Francisco Bay aided the U.S. Geological Survey study of tidal patterns and water movement.

## **DISASTER ASSESSMENT**

Firefighters have used U-2 high-altitude data for faster containment of fires, and direct savings of manpower, equipment, forest watersheds, and wildlife habitat were achieved. Flood damage surveys can help to assign priority for repairs and damage alleviation by providing pictures of the complete situation.

## **LAND USE**

In the Arizona Land Use Experiment, U-2 imagery was used to generate orthophotoquad maps, thereby developing a land use management data base for both the public and private sectors. U-2 photos have been used to evaluate urban growth, traffic patterns, and pollution, and have proved invaluable in the preparation of environmental impact statements.

## **SENSOR DEVELOPMENT**

The Ocean Color Scanner (OCS) imaging radiometer test flown on the U-2 prior to installation

on NASA's weather satellite Nimbus G is designed to remotely sense small variations in the ocean's color. The scanner identifies and maps regions of high food productivity, upwelling, tidal extent, sediment concentration off the coast, and will ultimately aid in coastal zone inventories. Similarly, the Heat Capacity Mapping Radiometer (HCMR) simulated on the U-2 is being evaluated for use in the detection of variations in soil moisture content, thermal pollution of water, and analysis of crop production prior to satellite flight.

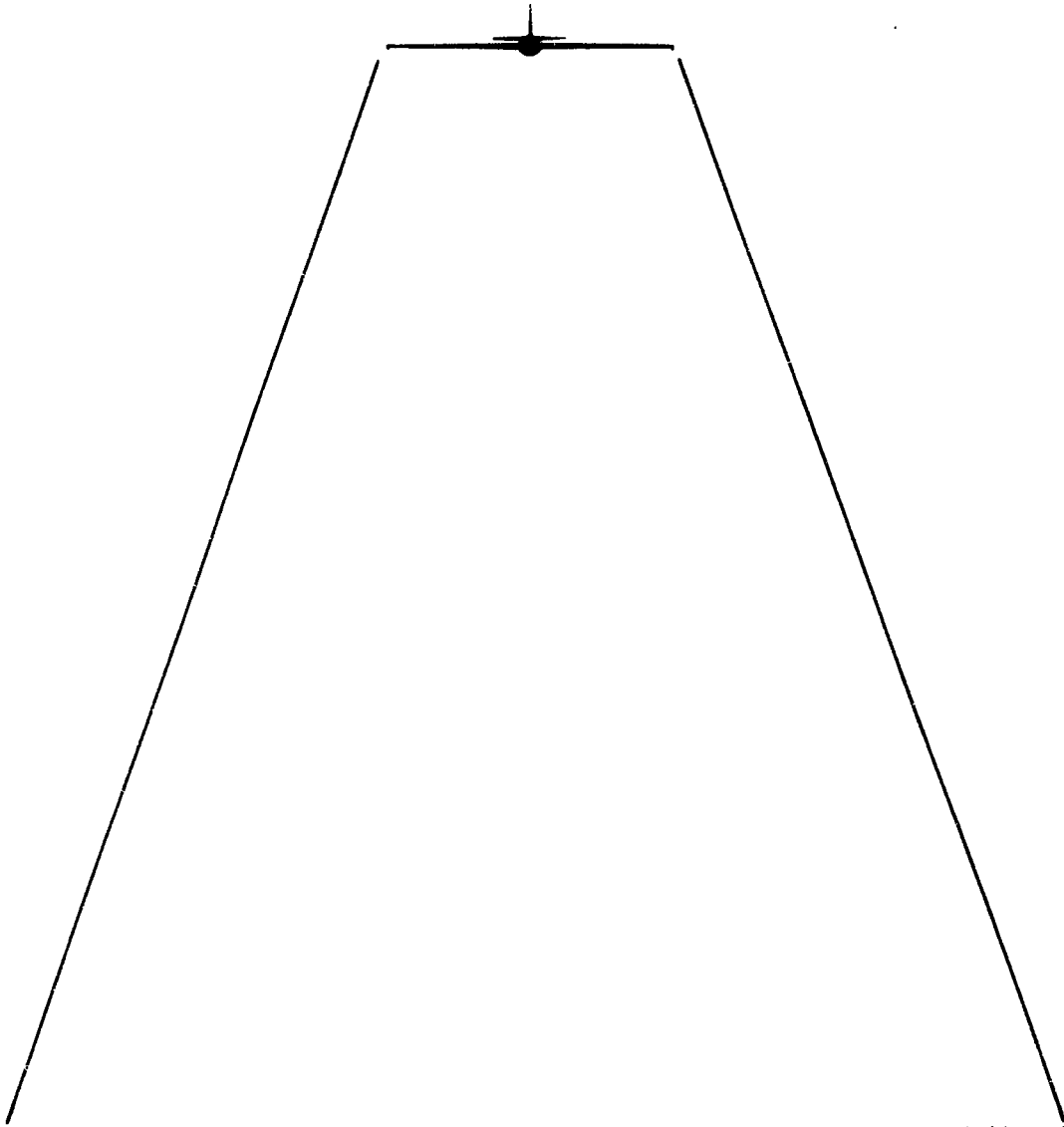
## **STRATOSPHERIC SAMPLING**

Special sensors on board the U-2 can sample and measure the distribution and extent of gases and aerosol particles in the atmosphere at altitudes above 20 km (65 000 ft.). A better understanding of the effects of natural and man-induced actions on the atmosphere's protective ozone layer will result.

## **SATELLITE SUPPORT**

The U-2 has been used extensively to collect underflight (or "ground truth") data to support Landsat investigations in forestry, water management, coastal zone processes, rangeland management, and land use. Multistage sampling techniques to aid in interpreting satellite data have been developed through the use of U-2 imagery.

# AIRCRAFT



The U-2 is a single-place aircraft designed and built by the Lockheed Aircraft Corporation for high-altitude, long-range operation. The U-2 is characterized by its long wing span and tandem landing gear located under the fuselage. Auxiliary gear, called pogos, are located outboard on the underside of each wing; they are jettisoned on takeoff.

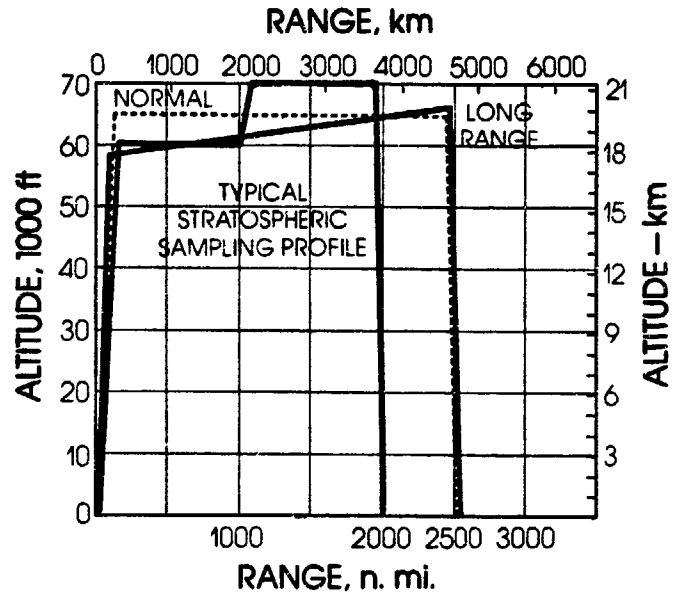
The NASA U-2 aircraft, based at Ames Research Center, routinely fly from Ames and Wallops Island, Virginia. Other staging locations are possible, and, data flights have been flown from Hawaii, Alaska, Texas, Maine, South Dakota, and Panama.

The high-altitude, long-duration capability of the U-2 makes it uniquely suitable for upper atmospheric or space-oriented research as well as for wide ranging electronic and photographic Earth observations. Since the beginning of NASA's Earth resources survey program at Ames Research Center in September 1971, each of the U-2's has averaged over 100 flights per year and together the aircraft have logged over 4000 flight hours.

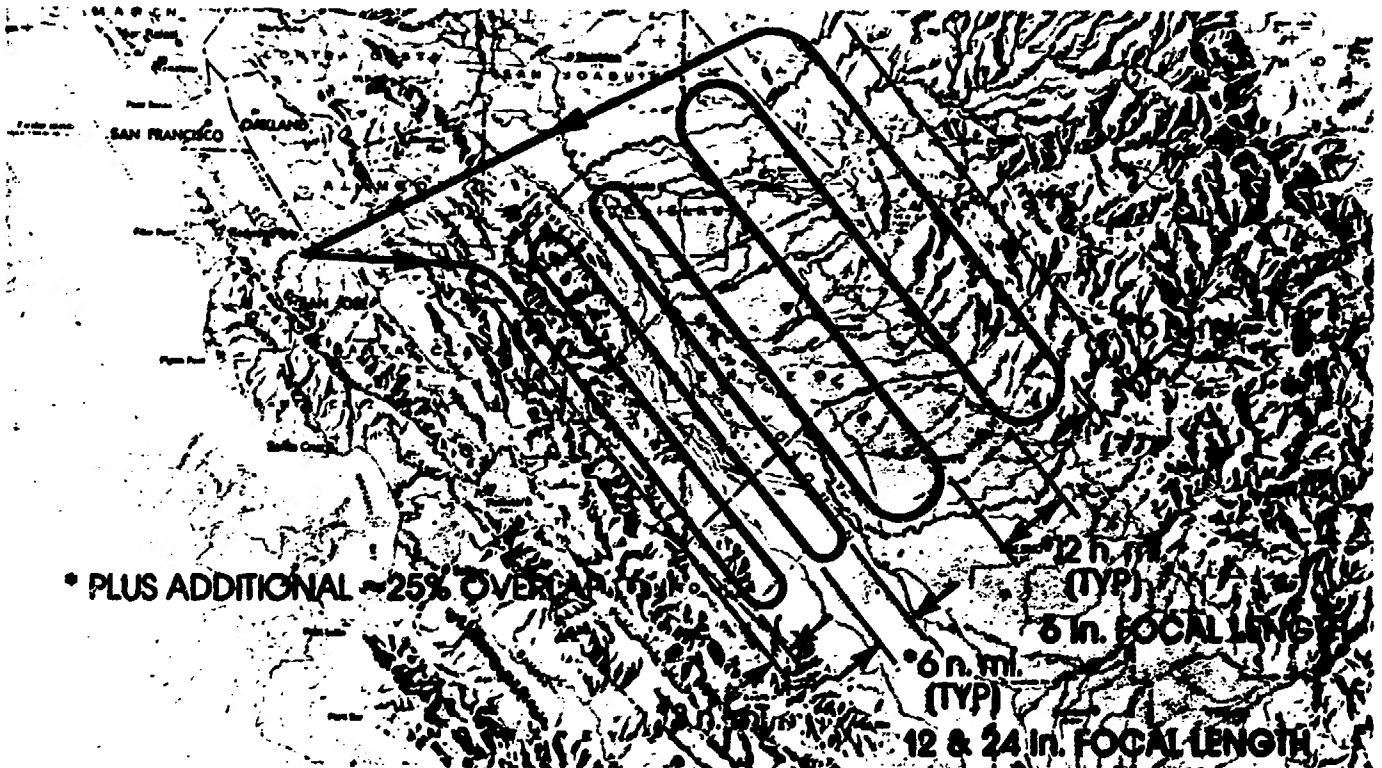
# U-2 PERFORMANCE AND DESIGN DATA

Range .....	.4700 km (2500 n. mi.)
Cruise .....	.6 hr at Mach 0.69
Operating altitude .....	19.8-21.3 km (65 000 to 70 000 ft)
Cruising speed .....	740 km/hr (400 knots) T.A.S. at 20 km (65 000 ft)
Gross takeoff weight .....	10 225 kg (22 542 lb)
Zero fuel weight .....	5 929 kg (13 071 lb)
Equipment bay payload .....	340 kg (750 lb) maximum; 225 kg (500 lb) preferred
Canoe payload .....	45 kg (100 lb)
Wing tanks (2) payload .....	135 kg (300 lb) each; 270 kg (600 lb) total
Total maximum payload .....	665 kg (1450 lb)
Fuel .....	3940 kg (8685 lb), 5000 liters (1320 gal.)
Powerplant .....	Single 15-stage, J75P-13B jet engine
Thrust rating .....	75 620 N (17 000 lb)
Construction .....	All aluminum
Crew .....	One pilot
Length .....	15.4 m (50 ft)
Wing span .....	24.4 m (80 ft)
Height .....	4.6 m (15 ft)

# TYPICAL FLIGHT PROFILE

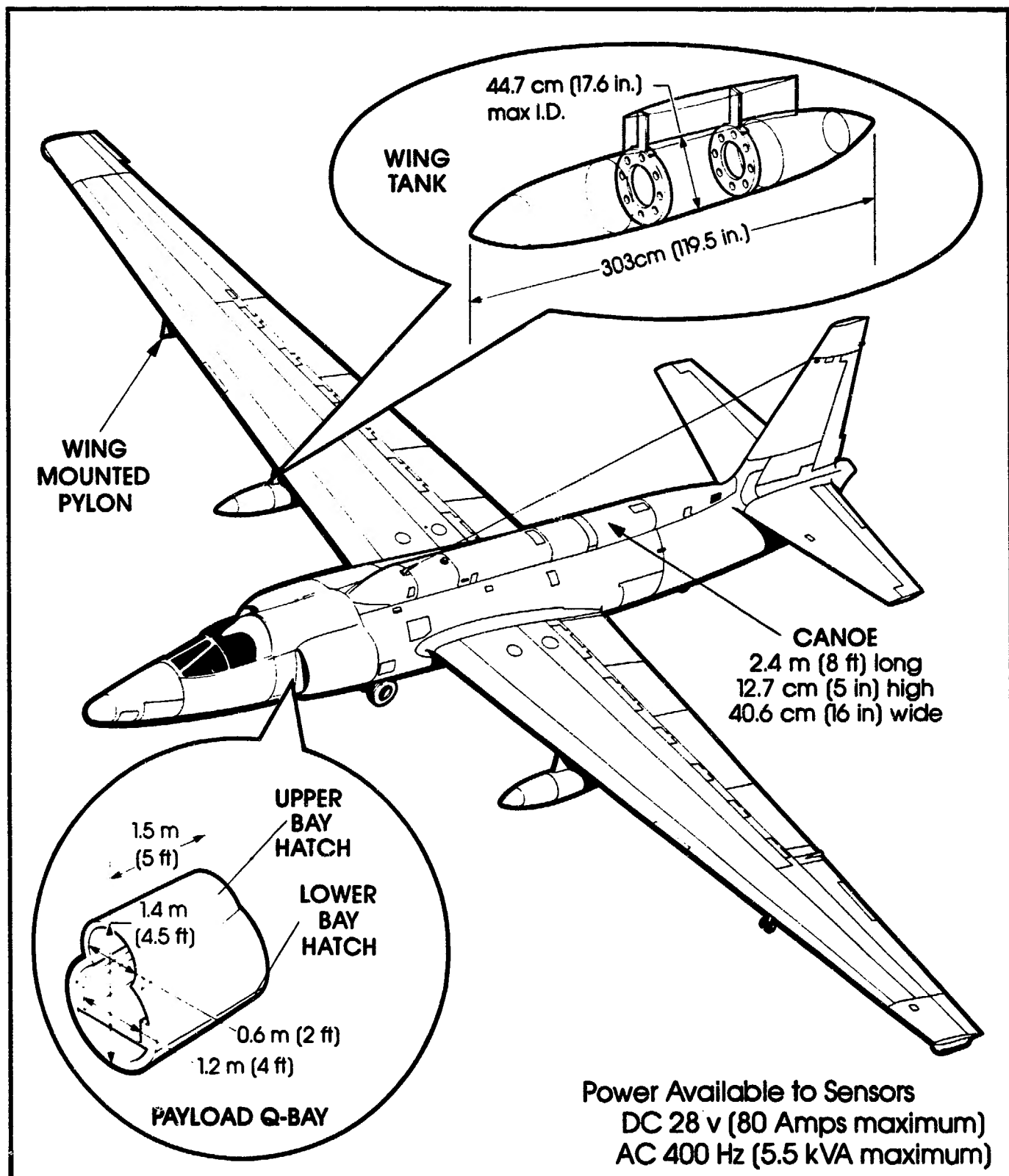


# TYPICAL GROUND COVERAGE PATTERN

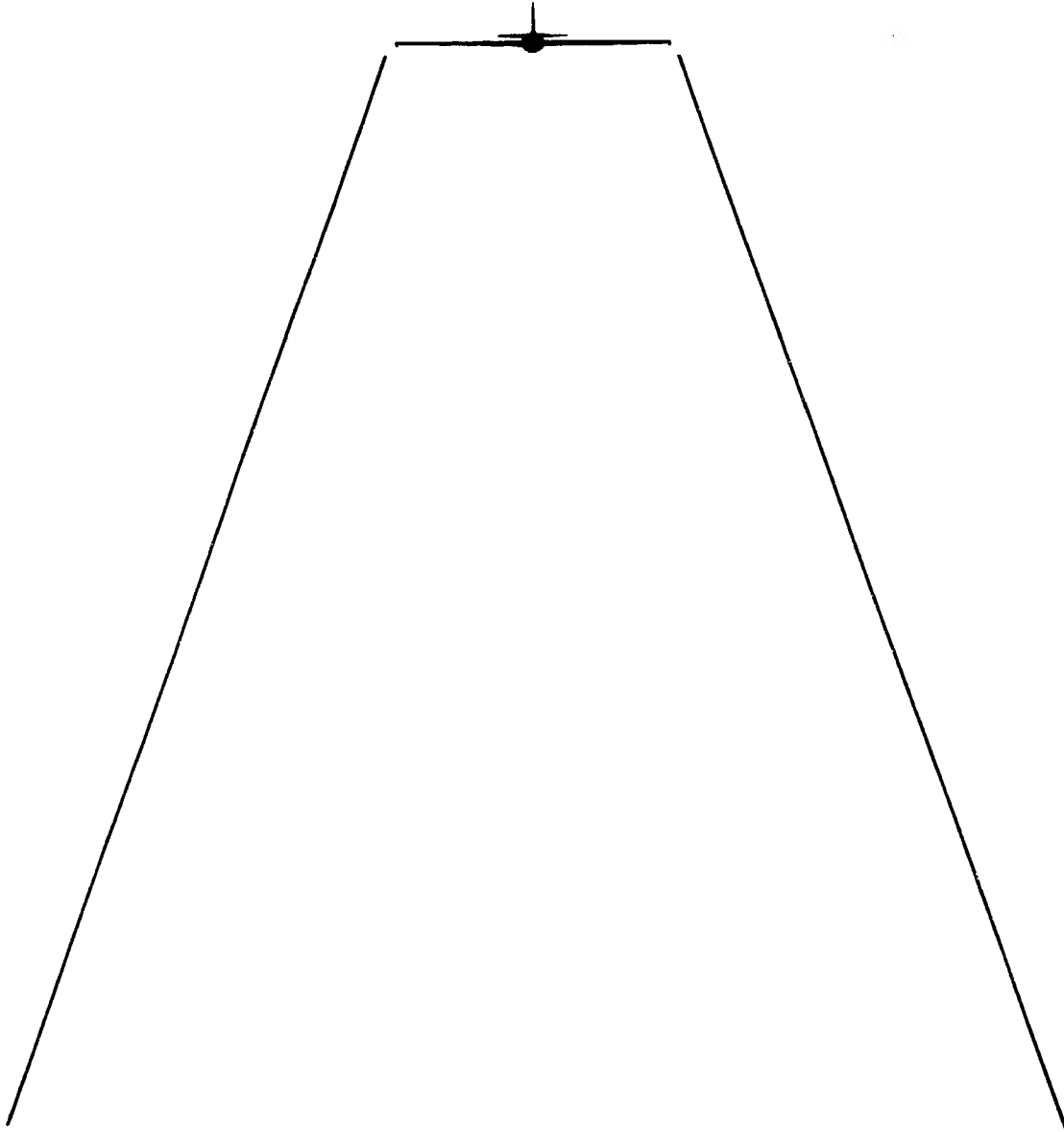




# PAYLOAD AREAS



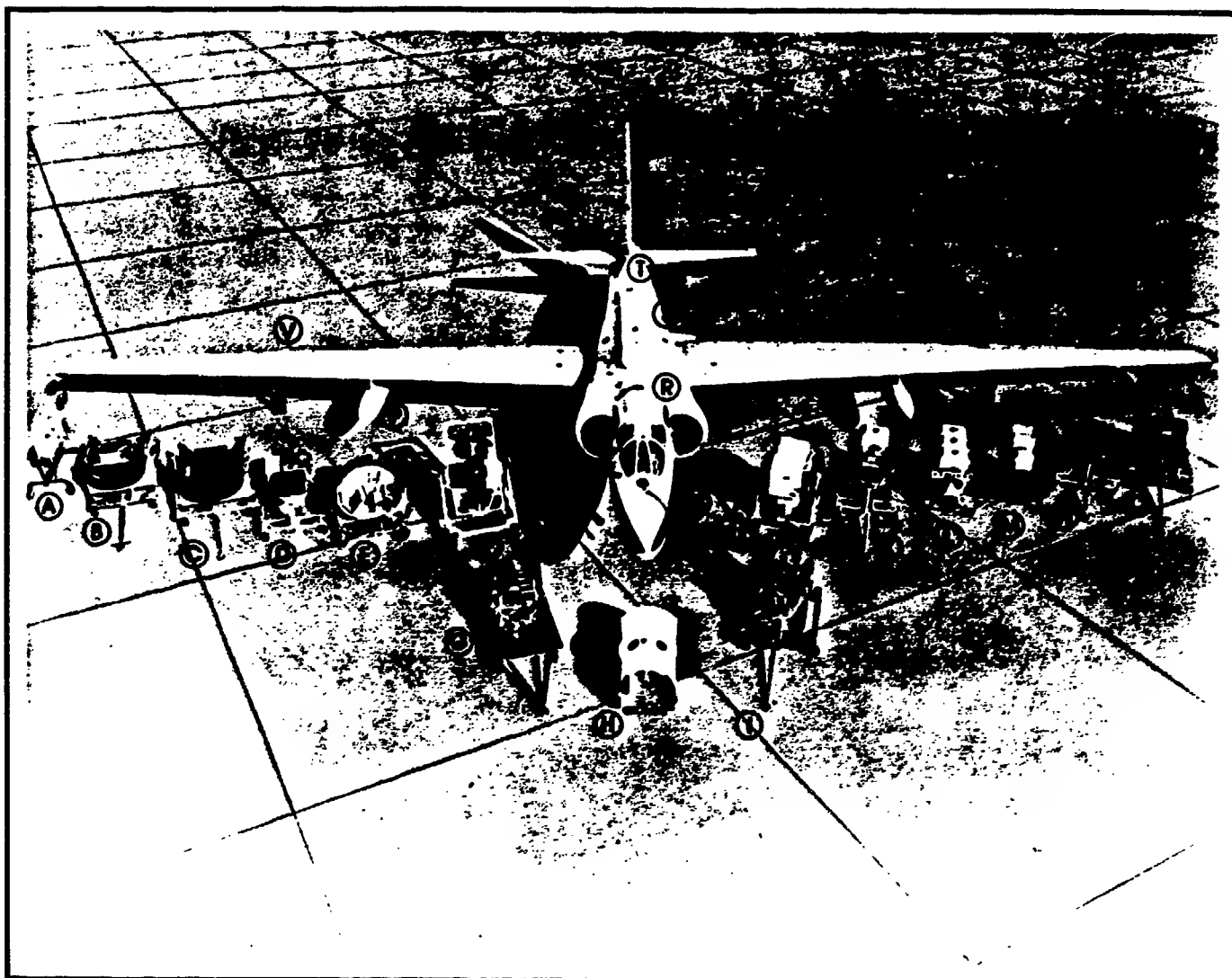
# SENSORS



The NASA U-2 aircraft routinely carry a variety of sensors, including aerial mapping cameras, electronic sensors and scanners, and both in situ and remote atmospheric sampling devices.

The U-2 has been used extensively for color infrared photography. An array of camera configurations — featuring a variety of focal lengths, film types, film format sizes, and multi-spectral capabilities — is available. Uses have varied, depending on the specific remote sensing research and development activity, but include direct evaluation of terrestrial conditions from imagery and the indirect use of imagery for satellite programs.

More than 15 nonphotographic sensors are also flown aboard the U-2; some are part of the NASA inventory but most of them have been built by outside investigators. The palletized system of payload handling facilitates switching payloads either in and out of the aircraft or from one aircraft to the other.

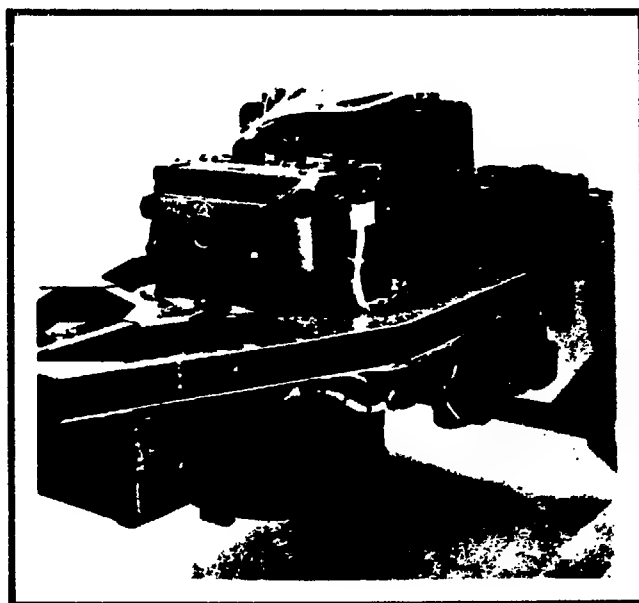


U-2 Sensor Complement

- |   |  |
|---|--|
| A TIRS (Thermal Infrared Scanner)             | M KA-80A Optical Bar Panoramic Camera        |
| B IRR (Infrared Radiometer)                   | N Dual RC-10 Camera System                   |
| C & D HCMR (Heat Capacity Mapping Radiometer) | O RC-10/Vinten Multispectral Camera System   |
| E Filter Sampler                              | P FLO (Infrared Spectrometer)                |
| F OCS (Ocean Color Scanner)                   | Q REFLEX (Resonance Fluorescence Experiment) |
| G SAS II (Stratospheric Air Sampler, Mark II) | R SEMIS (Solar Energy Measurements in Space) |
| H Aether Drift Radiometer                     | S CO <sub>2</sub> Collector                  |
| I SCS (Stratospheric Cryogenic Sampler)       | T H <sub>2</sub> O Vapor Radiometer          |
| J HR-73B Camera                               | U HSI (High Speed Interferometer)            |
| K RC-10/HR-732 Camera System                  | V APS (Aerosol Particulate Sampler)          |
| L HR-732 Tri-Vertical Cameras                 |  |

# PHOTOGRAPHIC SENSORS

NASA maintains an inventory of cameras that has been used extensively in Earth observation studies — particularly in support of satellite missions. Some camera payloads (or configurations) use four identically pointed 70-mm film cameras with filters to simulate the LANDSAT multispectral scanner. Higher resolution imagery is obtained by using 9-in. film with 6-in., 12-in., 24-in., or 36-in. focal length lenses. Although the 6-in. and 12-in. lenses are used with a 9 x 9 in. image format, the 24-in. and 36-in. lenses are frequently used to make a 9 x 18 in. negative or transparency. The ground coverage and resolution are a function of lens focal length and film format. The values of these parameters for the different camera configurations are shown on pages 12 and 13 for an aircraft altitude of 20 km (65 000 ft). An indication of resolution is also evident in the enlarged images on page 14.



U-2 payload pallet with camera configuration that includes one RC-10 (forward) and four Vintens (rear).

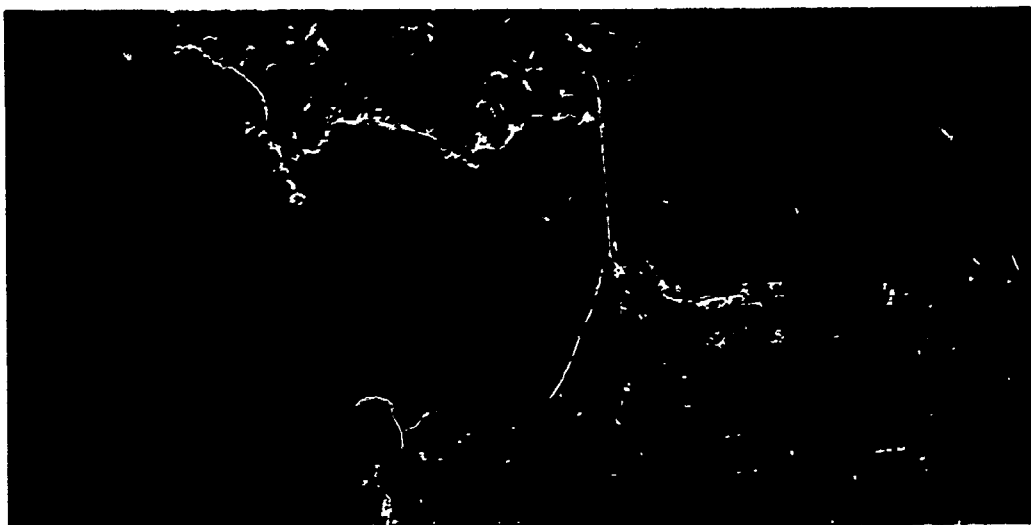
A variety of film types is used, depending on the intended use of the imagery. Included, for example, are Panatomic-X Aerial and Plus-X black and white, Infrared Aerographic, B & W infrared, Aerochrome (color) Infrared, Aerial Color and Ektachrome EF Aerographic natural color films. Sample images using three film types are shown on page 10. Some of the interpretations of color infrared film (which is the most popular type used) are described below the image on page 11.

Each frame of imagery is automatically annotated with a 16-digit code indicating the sensor, film type, date, and time of exposure. All imagery is indexed and archived in the U-2 Data Facility. A map of existing coverage is shown on page 16.

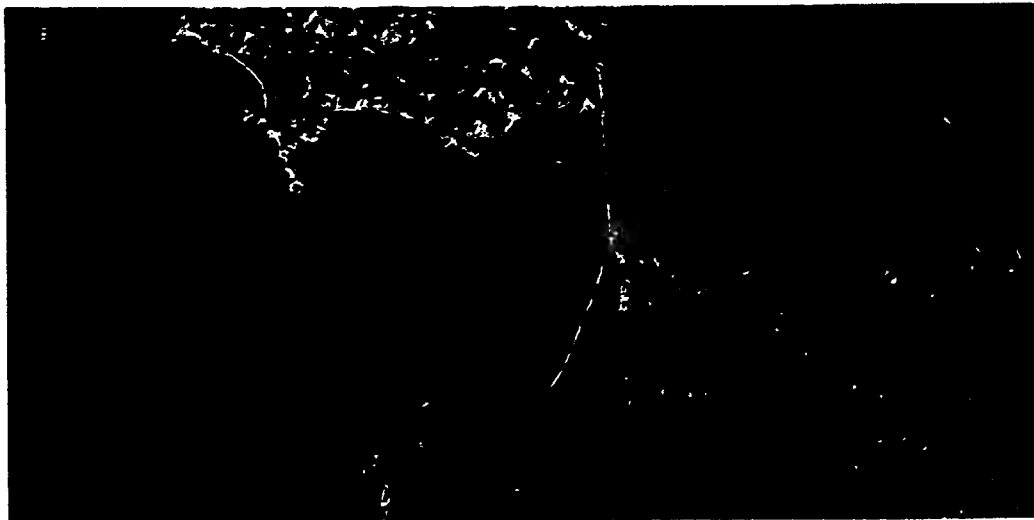
San Francisco.  
24 in. lens, 9 x 18 in.  
Black and white film.

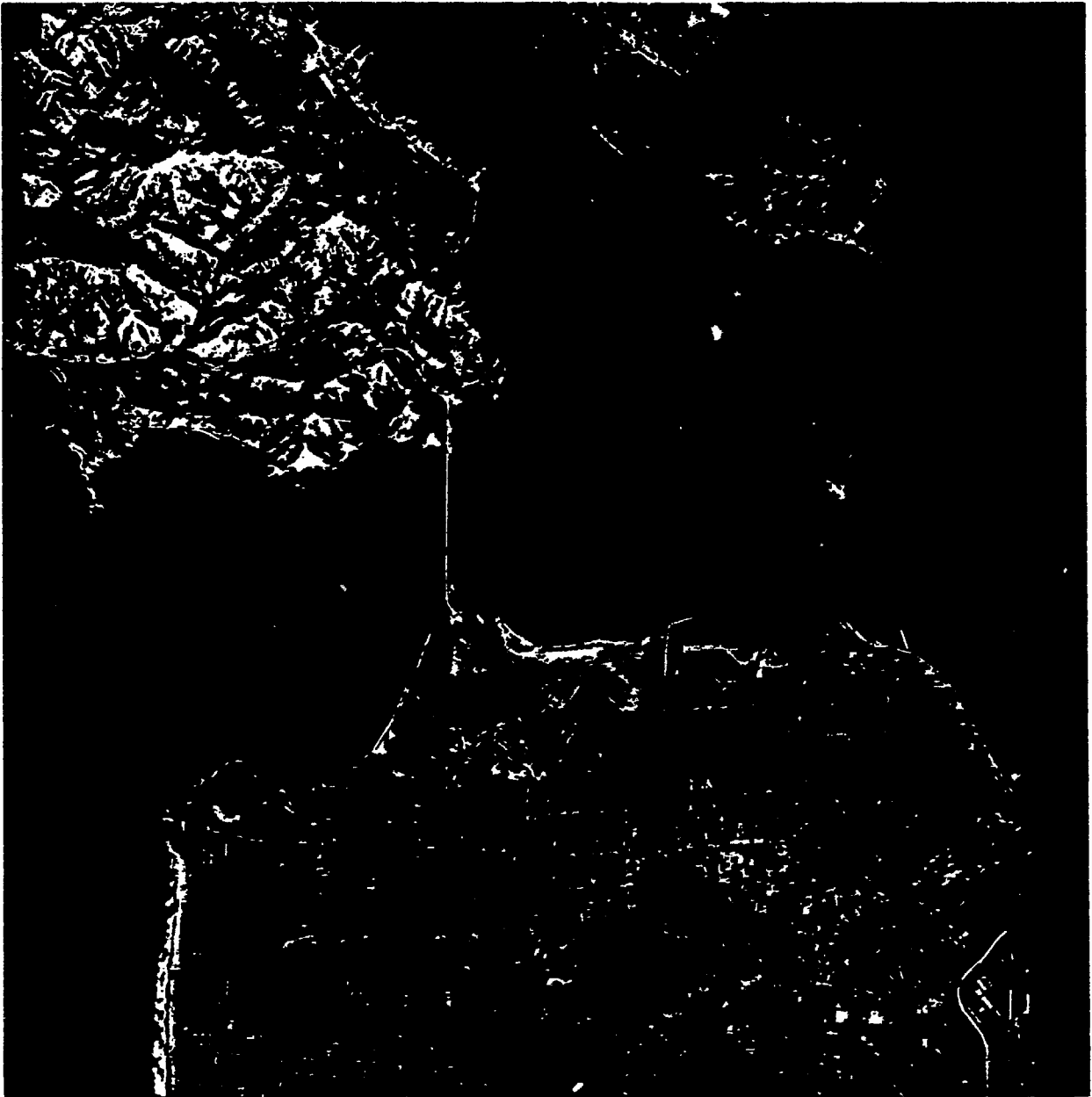


San Francisco.  
24 in. lens, 9 x 18 in.  
Natural color film.



San Francisco.  
24 in. lens, 9 x 18 in.  
Color IR film.





Color infrared photograph of San Francisco and the Golden Gate obtained by NASA U-2 aircraft on February 5, 1974

The photograph of San Francisco and the Golden Gate was taken from an altitude of 62 500 feet (19 000 m) with a Wild-Heerbrug RC-10 camera, 12-in. (305 mm) focal length. The area covered is about 60 square nautical miles.

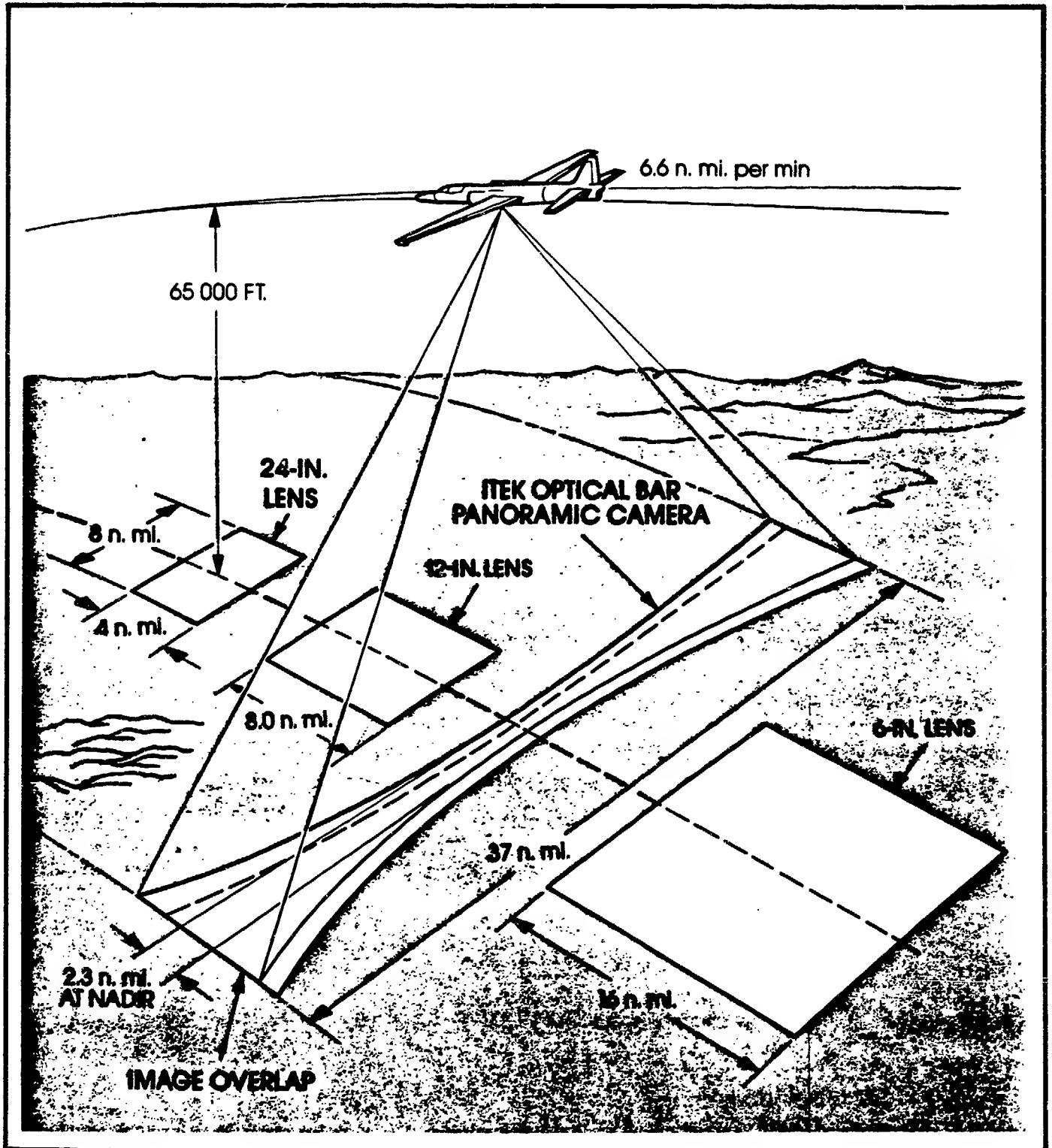
Color infrared film is sensitive to the green, red, and near infrared (500-900 nm) portions of the spectrum and is widely used in aerial and space photographic surveys for land use and vegetation analysis. Living vegetation reflects light in the green portion of the visible spectrum to which the human eye is sensitive. Additionally, it reflects up to 10 times as much in the near

infrared (700-1100 nm) portion of the spectrum which is just beyond the range of human vision. When there is a decrease in photosynthesis, whether caused by normal maturation or stress, there is a corresponding decrease in near infrared reflectance. Living or healthy vegetation appears as various hues of red in color infrared film. If diseased or stressed, the color response will shift to browns or yellows due to the decrease in near infrared reflectance. This film is also effective for haze penetration because blue light is eliminated by filtration.

# CAMERA CONFIGURATIONS

Designation	Lens	Film Format, in.	Ground Coverage @ 65 000 ft	Nominal Resolution @ 65 000 ft
Vinten (Four)	1-3/4 in. f.l. f 2.8	70 mm (2-1/4 x 2-3/16)	25.9 x 25.9 km (14 x 14 n. mi.) (Each)	10 – 20 m
I <sup>2</sup> S Multispectral (four bands) K-22	100 mm f.l. f 2.8	9 x 9 (4 @ 3.5)	16.7 x 16.7 km (9 x 9 n. mi.)	6 – 10 m
RC-10	6 in., f 4	9 x 9	29.7 x 29.7 km (16 x 16 n. mi.)	3 – 8 m
RC-10	12 in., f 4	9 x 9	14.8 x 14.8 km (8 x 8 n. mi.)	1.5 – 4 m
HR-732	24 in., f 8	9 x 18	7.4 x 14.8 km (4 x 8 n. mi.)	0.6 – 3 m
HR-73B-1	36 in., f 10	18 x 18	9.8 x 9.8 km (5.3 x 5.3 n. mi.)	0.5 – 2 m
Itek Panoramic (Optical Bar)	24 in., f 3.5	4.5 x 50	3.7 x 68.6 km (2 x 37 n. mi.)	0.3 – 2 m
Research Camera System (RCS)	24 in., f 3.5	2-1/4 x 30	2 x 20 km (1.1 x 11 n. mi.) useable	0.1 – 1 m

# CAMERA GROUND COVERAGE

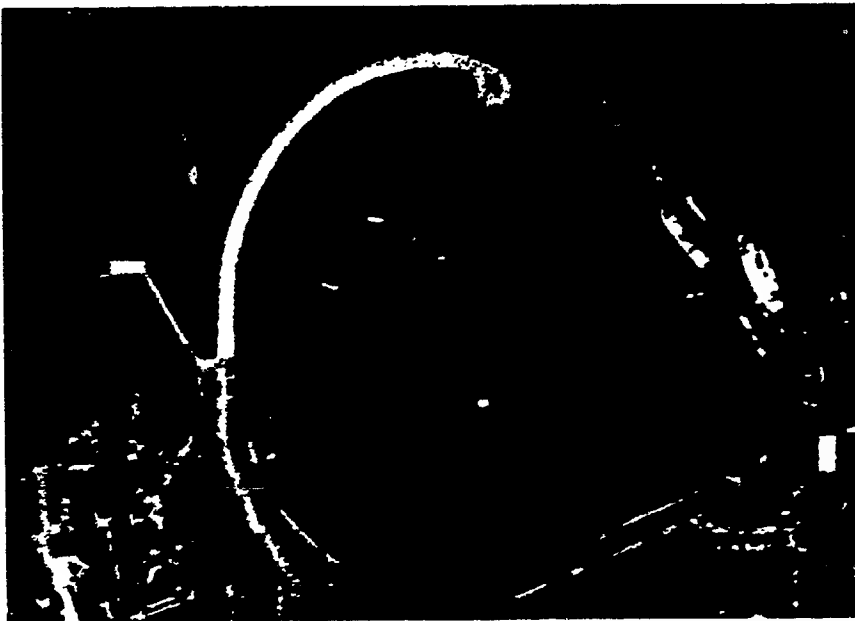




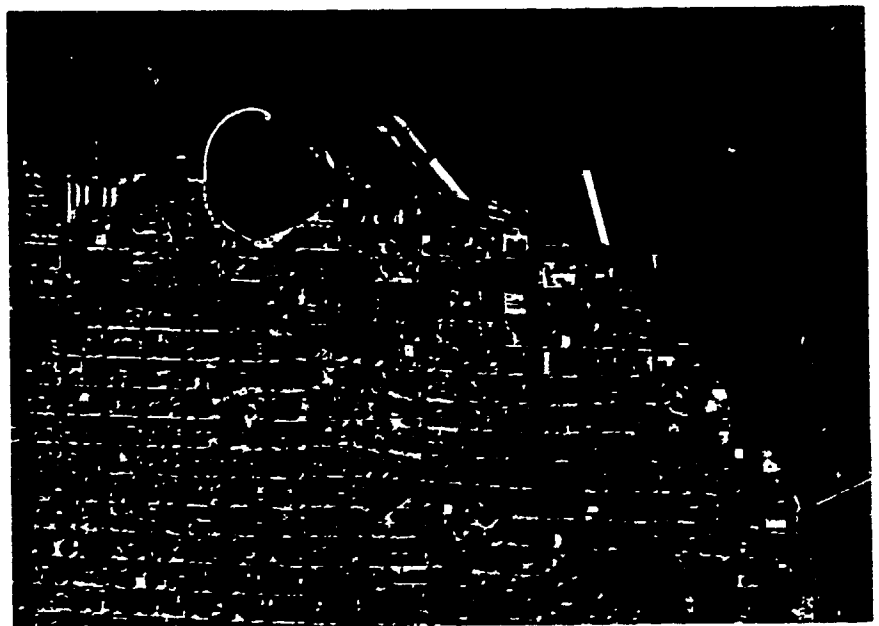
# RESOLUTION

Image resolution is determined primarily by lens focal length because the subject distance is fixed at about 20 km (65 000 ft) from the U-2. Lens quality, film type, image contrast, and a number of other related factors also affect resolution. Images from a 6-in. and a 24-in. lens are

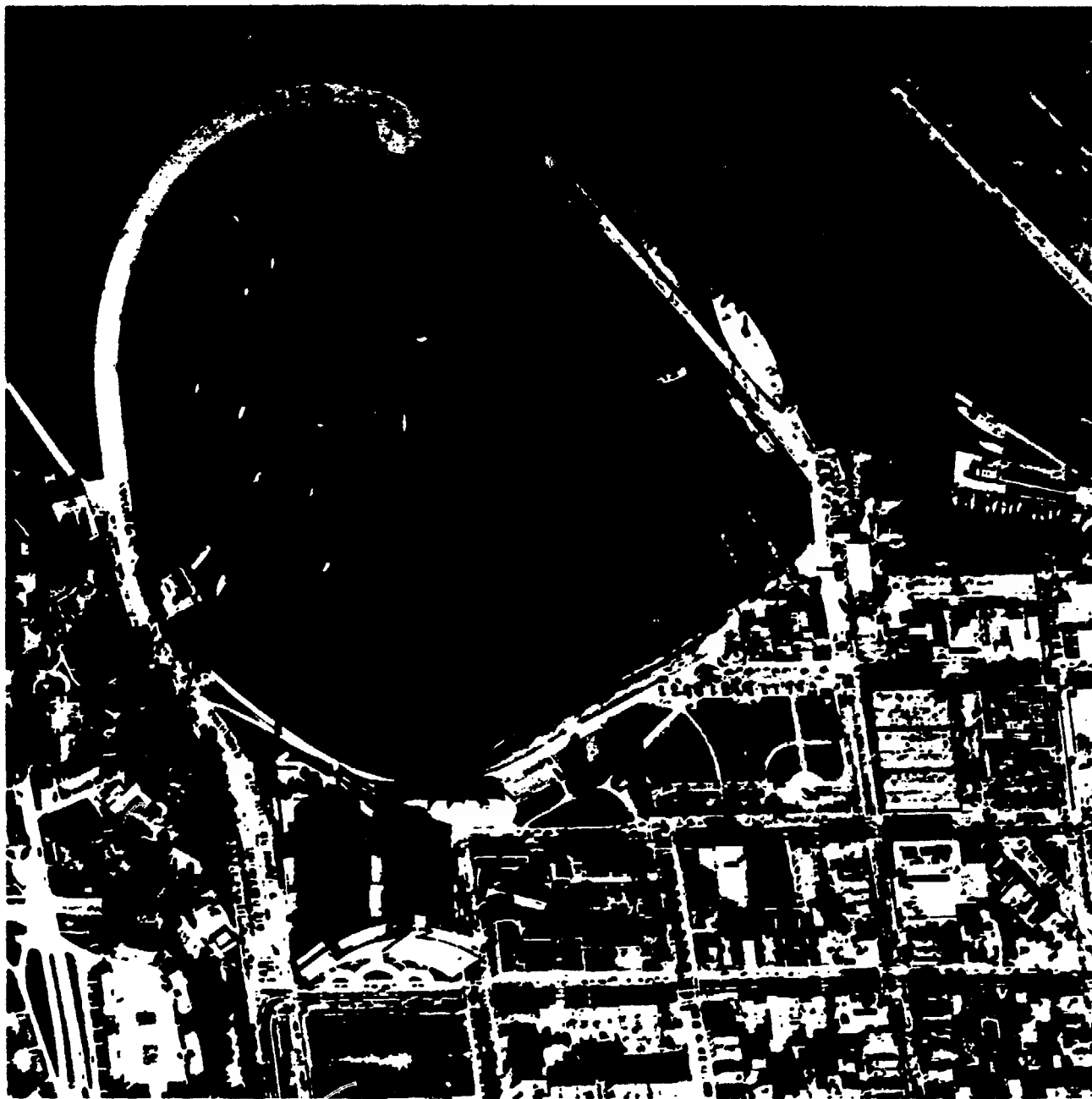
compared at 5X enlargement to illustrate resolving power. Normally, the maximum practical enlargement is limited to about 10X because of film grain and image sharpness. However, any enlargement factor can be utilized for the convenience of maps or other data base overlay.



Detail from 24-in. lens.  
scene of San Francisco  
in color infrared (from  
page 10).  
5X enlargement



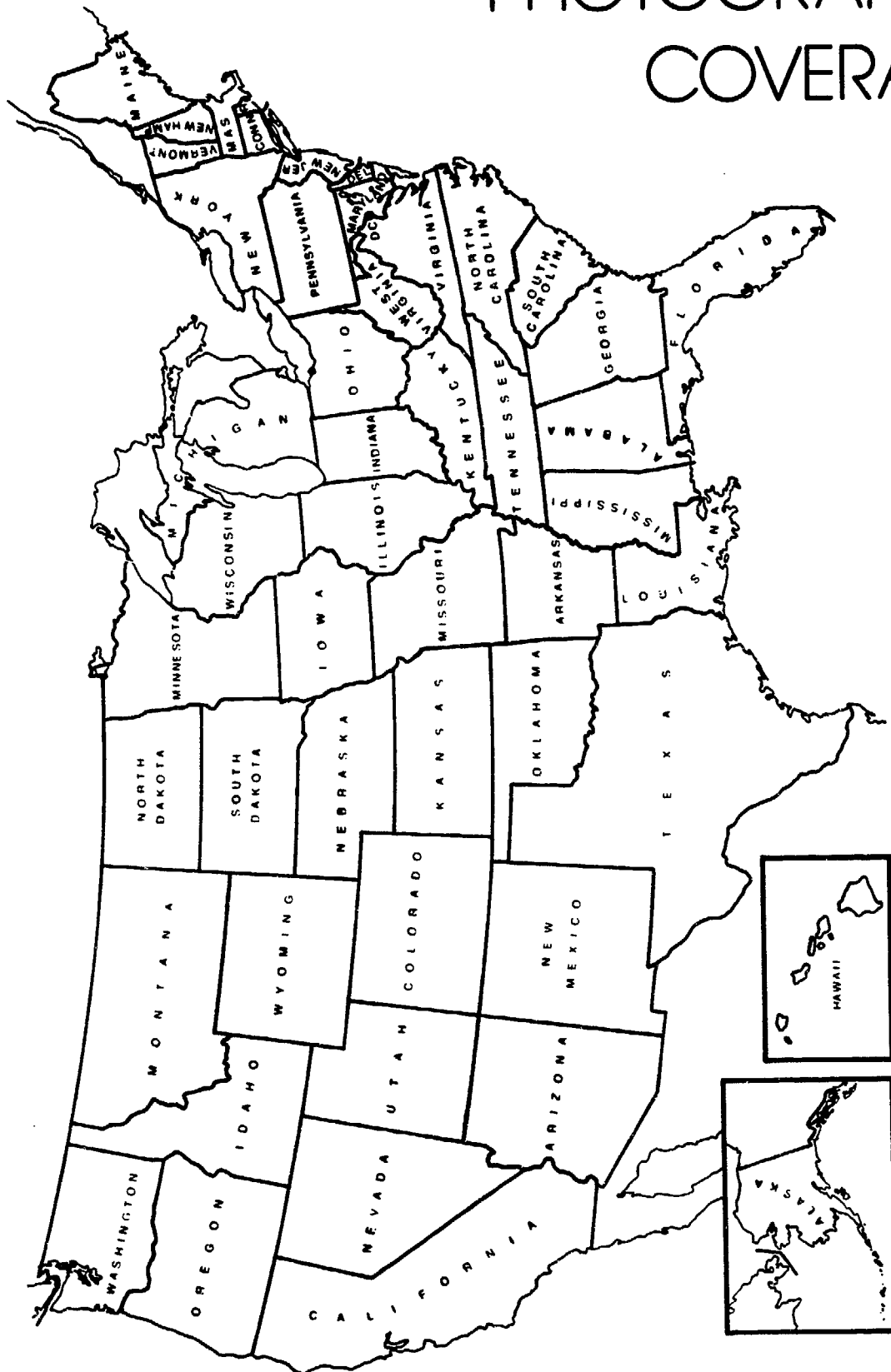
Detail from 6-in. lens  
scene of San Francisco  
in color infrared.  
5X enlargement



Portion of an RCS image at an 10x enlargement of San Francisco scene.

The Research Camera System (RCS) is designed for high resolution over moderately large areas. The system consists of two panoramic cameras mounted to provide convergent stereo coverage. Each camera has a 24 in. focal length lens and uses a 2-1/4 x 30 in. film format.

# PHOTOGRAPHIC COVERAGE

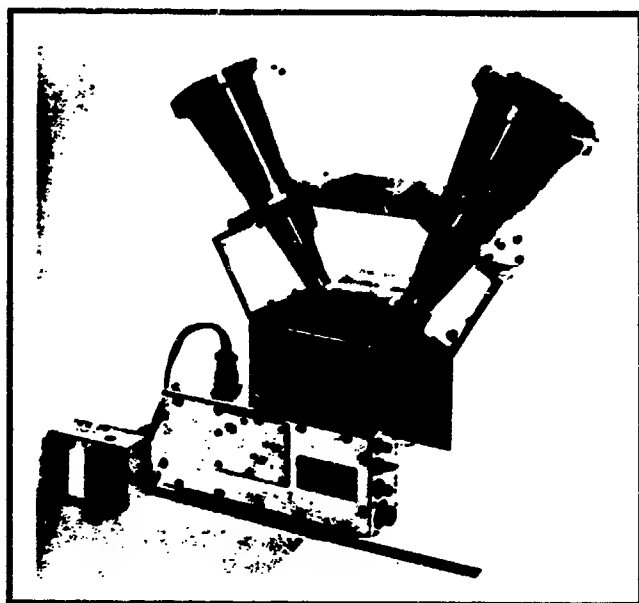


Available photographic coverage of United States by U-2 as of January 1, 1978.

# NONPHOTOGRAPHIC SENSOR ACCOMMODATIONS

Most nonphotographic sensors installed on the U-2 are user-supplied and funded. An investigator's equipment can be installed in several areas on the U-2 subject to load factors, safety standards, and construction constraints.

A special equipment bay, pressurized and heated, holds a maximum of 340 kg (750 lb). This bay, termed the Q-bay, is located just aft of the cockpit and is the principal location for special equipment packages. The bay has top and bottom hatches that are easily removed by means of external latches. Racks to support or contain electronics or other equipment generally must be made to fit the equipment bay attachment points. Several universal rack designs are available that can support up to 340 kg (750 lb).



Aether drift radiometer

Each of the two wing tanks can hold up to 135 kg (300 lb) at ambient pressure and temperature. In addition, 45 kg (100 lb) of equipment can be supported in the upper fuselage in a section termed the canoe also at ambient conditions.

Most investigators choose to provide their own recorder, although a high-density M14E magnetic tape data recorder is available.

Specifications on packaging constraints, electrical power, navigation equipment, and radio communications will be furnished on request.

At the present time, investigators are using nonphotographic sensor packages on the U-2 for research in astronomy and astrophysics, stratospheric and atmospheric studies, and Earth observations. Examples of nonphotographic sensor packages flown on the U-2 are described in the following pages.

# NONPHOTOGRAPHIC SENSORS

**ASTRONOMY AND ASTROPHYSICS RESEARCH** is being conducted with the U-2 by the Lawrence Berkeley Laboratory (LBL) and NASA's Goddard Space Flight Center.

Physicists at the Lawrence Berkeley Laboratory are using two upward-looking microwave radiometers installed on the U-2 in an experiment entitled "Aether Drift." They are studying and mapping the temperature of deep space to examine some fundamental questions about the origin of the universe.

Investigators at Goddard Space Flight Center have placed an instrument on board the U-2 to measure solar spectral radiance and its variation with the solar cycle. This instrument is being developed for future use in a spacecraft for measurements in space.

**EARTH OBSERVATIONAL SYSTEMS** are being developed by Goddard Space Flight Center and Ames Research Center using the U-2 platform to evaluate data prior to installation of instrumentation on spacecraft.

**THE HEAT CAPACITY MAPPING RADIOMETER** consists of a two-channel scanning radiometer that images in the visible and thermal infrared bands. Investigations include studies of thermal pollution, wetlands, and soil moisture. The system is being evaluated prior to spacecraft flight.

**THE OCEAN COLOR SCANNER (OCS)** is a 10-channel multispectral scanner designed for water color measurements at high altitude. It is the forerunner of the Nimbus G Coastal Zone Color Scanner. Installed on the U-2 the OCS has been used to detect subtle variations in the upwelling spectral radiance emerging from natural waters.

**THE HRB-454 THERMAL SCANNER** is an IR line scanner owned and operated by the U-2 Facility at Ames Research Center for use by interested investigators. The video system is roll-stabilized and a Vinten camera is installed as a track camera.

**HIGH ALTITUDE MULTISPECTRAL SCANNER** is a modified Daedalus 11-channel system with the capability of supporting LANDSAT investigations. This scanner is available to NASA through a cooperative agreement with the Environmental Protection Agency. The system is entirely digital with ten channels in the visible/near-visible spectral region and one channel in the thermal infrared.

**LINE SCAN CAMERA** is a visible imaging system which is designed to provide real-time imagery to a ground receiving station via a telemetry data link. This imagery can be used for real-time forest fire or disaster observations.

**STRATOSPHERIC AND ATMOSPHERIC STUDIES** are represented in a number of diverse sensor systems, some of which are described below.

**THE AMES STRATOSPHERIC AIR SAMPLER II** is a 4-channel, 500-lb instrument carried in the equipment bay. It utilizes chemiluminescent reactions to continuously measure  $O_3$ ,  $NO$ ,  $NO_2$ , and  $HNO_3$  in atmospheric samples drawn aboard the aircraft. Studies of seasonal and geographic variations in these important stratospheric species are then made as part of an overall program at Ames in stratospheric studies.

**THE CRYOGENIC AND WHOLE AIR SAMPLER** instrument contains four cryogenically cooled samplers plus two whole-air samplers for

collecting halocarbons (Freons),  $\text{N}_2\text{O}$ ,  $\text{CCl}_4$ , and other condensible species for later analysis by gas chromatography at Ames Research Center. Concentrations below 1 part per trillion can be detected.

THE INFRARED SCANNING SPECTROMETER is a liquid-helium cooled 135 kg (300-lb) instrument mounted in an underwing pod; it views the atmosphere at  $10^\circ$  above the horizon. The 7- to  $13\text{-}\mu\text{m}$  spectral region is scanned where emissions from  $\text{O}_3$ ,  $\text{N}_2\text{O}$ ,  $\text{CH}_4$ ,  $\text{CFCl}_3$  (Freon 11),  $\text{CF}_2\text{Cl}_2$  (Freon 12),  $\text{HNO}_3$ ,  $\text{H}_2\text{O}$ , and  $\text{CO}_2$  are observed and amounts determined. Data are recorded on a digital tape recorder for subsequent analysis by the University of Denver, where the sensor was developed.

THE HIGH-SPEED MICHELSON INTERFEROMETER, installed on the U-2 by scientists at JPL, views the Sun at sunrise or sunset in the IR (2 to  $5.5\text{ }\mu\text{m}$ ) and determines the amount of various stratospheric species— $\text{H}_2\text{O}$ ,  $\text{HCl}$ ,  $\text{CO}_2$ ,  $\text{CH}_4$ ,  $\text{NO}_2$ , and  $\text{N}_2\text{O}$ —in the intervening atmosphere. This instrument will aid in the design and evaluation of future instrumentation for monitoring specific atmospheric pollutants.

THE FILTER SAMPLER, an Ames instrument, consists of six 16-in.-diameter filter elements that selectively collect  $\text{HCl}$ , other halogen compounds, and aerosols for later laboratory analysis. The chemically impregnated filter papers are exposed to the airstream by pilot command.

THE WATER VAPOR RADIOMETER, an upward-looking instrument, measures atmospheric radiation in selected regions of the water vapor emission bands and determines the total amount of water vapor above the U-2. The data

are sampled every 10 sec and recorded in digital format on magnetic tape for subsequent data reduction and analysis at the National Oceanic and Atmospheric Administration (NOAA).

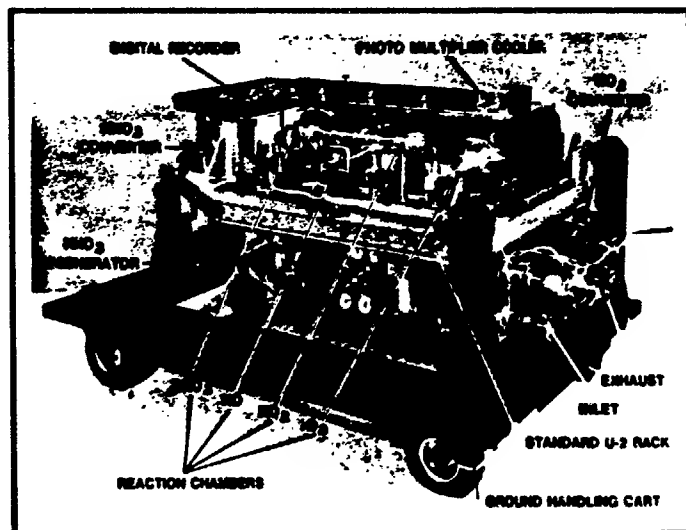
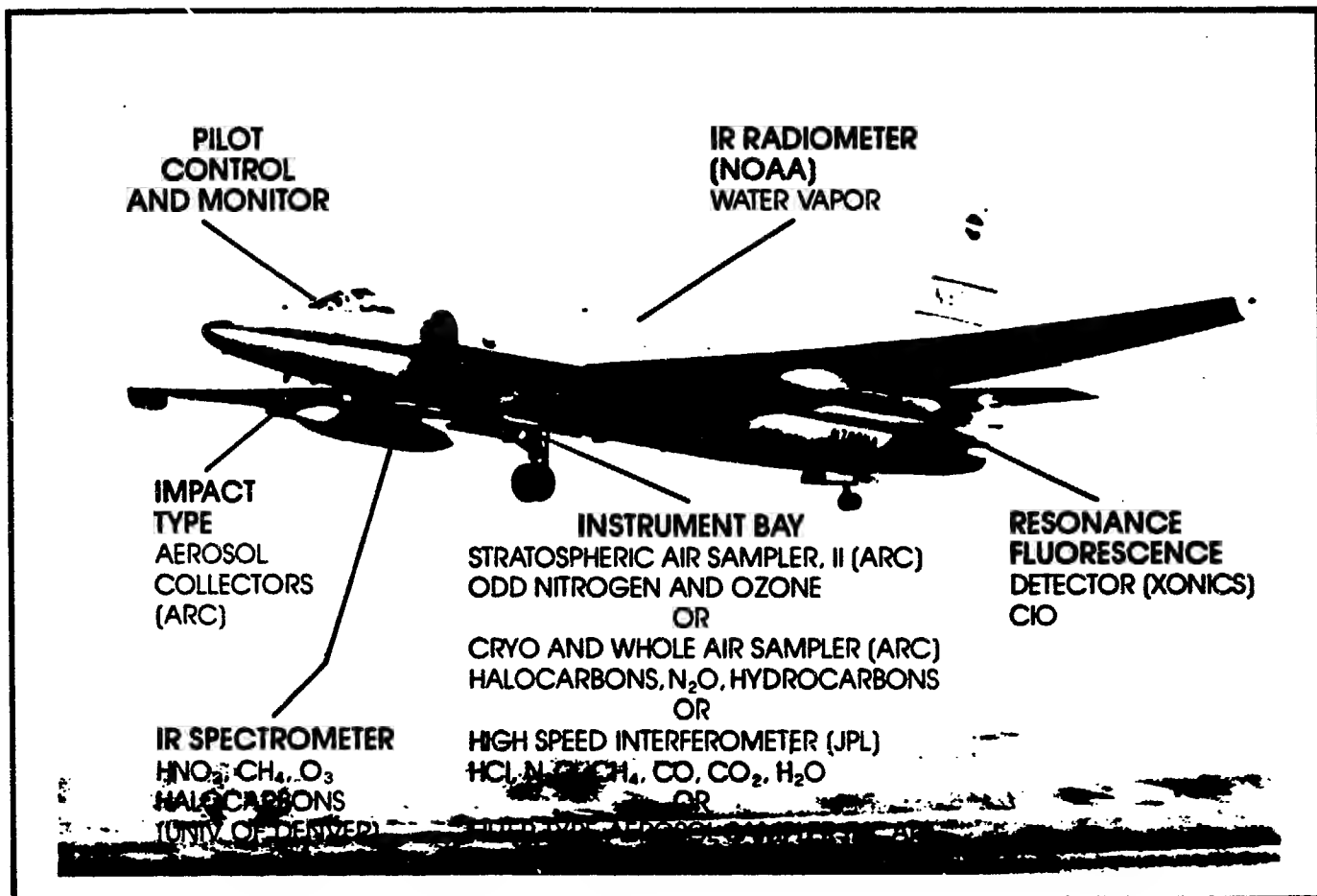
THE AEROSOL PARTICLE SAMPLER employs small wire meshes that are exposed to the airstream from a wing tip pod on pilot command. The size, shape, and chemical composition of the impacting stratospheric aerosols are determined by a laboratory scanning electron microscope and its X-ray spectra attachment at Ames. Particles as small as  $0.1\text{ }\mu\text{m}$  can be collected and counted.

THE RESONANCE FLUORESCENCE EXPERIMENT is an underwing, pod-mounted, developmental instrument that uses the phenomenon of resonance fluorescence to detect very small amounts of a selected species. It is presently configured to measure  $\text{ClO}$ , of great importance to our understanding of the effects of halocarbons (Freons) on the stratospheric ozone balance.

THE  $\text{CO}_2$  COLLECTOR is a small system used by an investigator at UCLA; it is activated from the cockpit by the pilot at cruise altitude. This system collects a free-air sample for laboratory research and analysis to assist a study of the global climate and high-altitude environment.

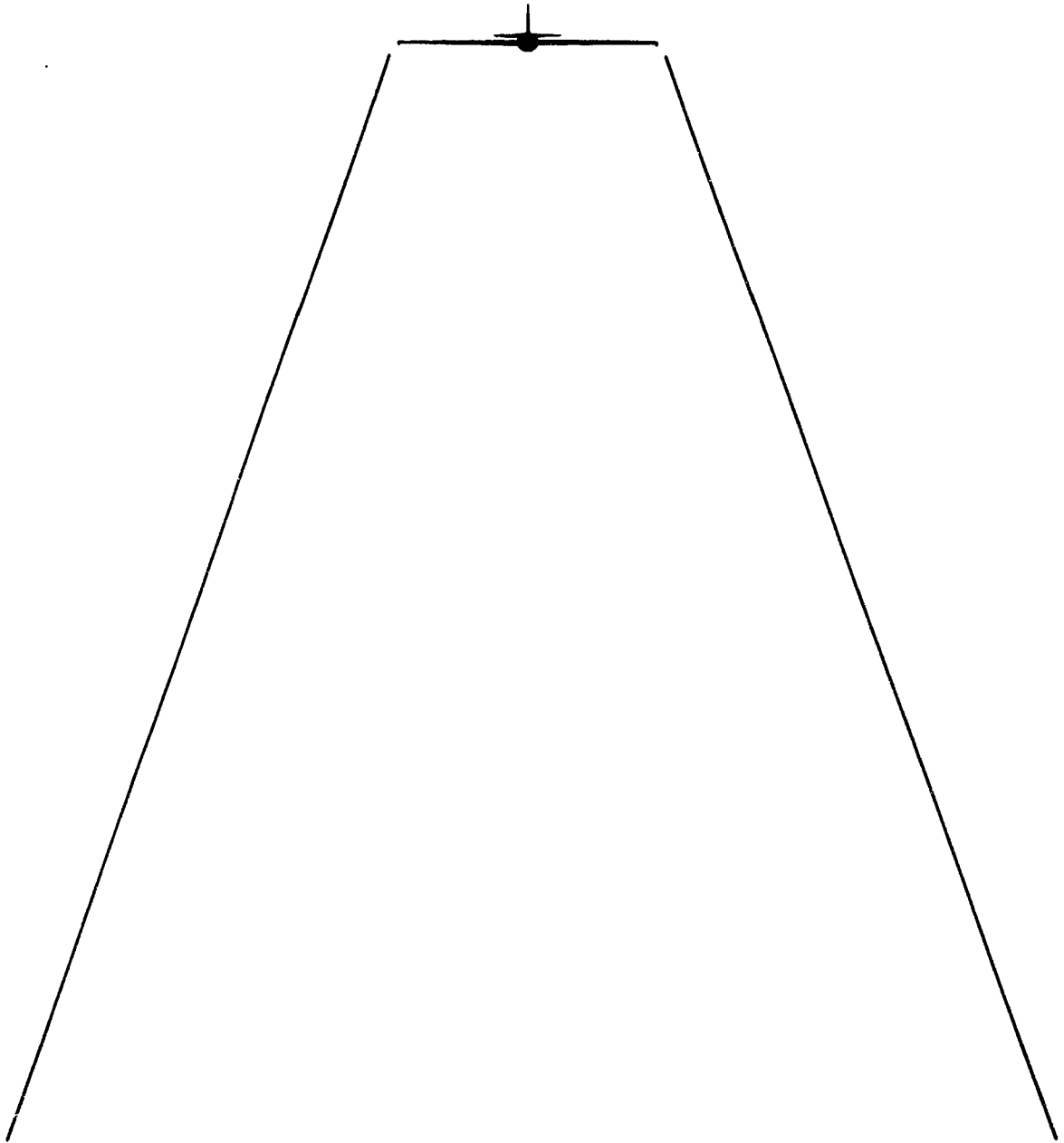
THE INFRARED RADIOMETER is a downward-looking radiometer. It has a rotating filter wheel that can see six spectral bands and measures atmospheric nonuniformities. The data on convective instabilities and mixing processes in the atmosphere will be useful in studies being conducted by Lockheed Laboratories in Palo Alto.

# STRATOSPHERIC SENSOR PAYLOADS



Stratospheric Air Sampler, Mark II

# DATA HANDLING



An aircraft support Data Facility at Ames Research Center is responsible for maintaining complete flight documentation, a computerized image storage and selection system, copies of all imagery, a microfilm browse file, and a variety of light tables and optical image viewing equipment. If arrangements are made in advance, all imagery is available for viewing by visitors, and photocopies of imagery may be made with the visitors' own equipment. By established policy, all NASA Earth resource imagery, both satellite and aircraft, is in the public domain. Full-scale reproductions of imagery are available through only the EROS DATA CENTER. A price list and order forms can be obtained from the EROS Data Center, Sioux Falls, South Dakota 57198. For more information, call (605) 594-6151.



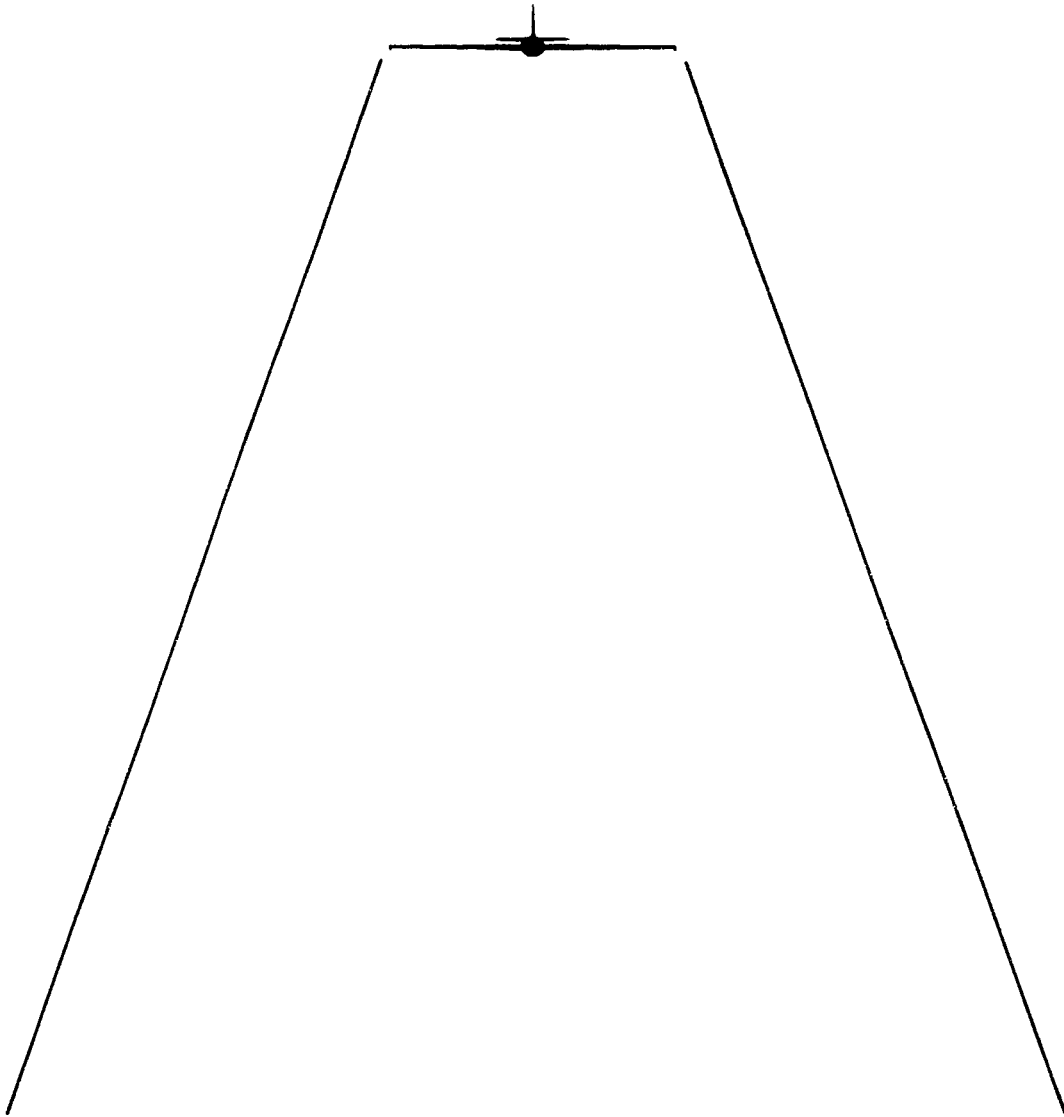


Data Entry System, light table configuration

Flight summary reports are published for each data collection flight. These brief reports list the sensors used and the kinds of data collected. They also contain a track map showing the location of individual data runs. The Data Entry System is used to compile descriptive data for each image in a computerized memory bank with the use of a digitizer tablet and reference maps as shown above. The data can then be

retrieved through the computerized Image Selection System via a graphics terminal. Available images can be identified according to geographic location, imagery scale, film type, data format, cloud cover, quality, spectral band, etc. Selected scenes can then be viewed quickly and easily with the microfilm browse file for final assessment before the actual imagery is retrieved for viewing.

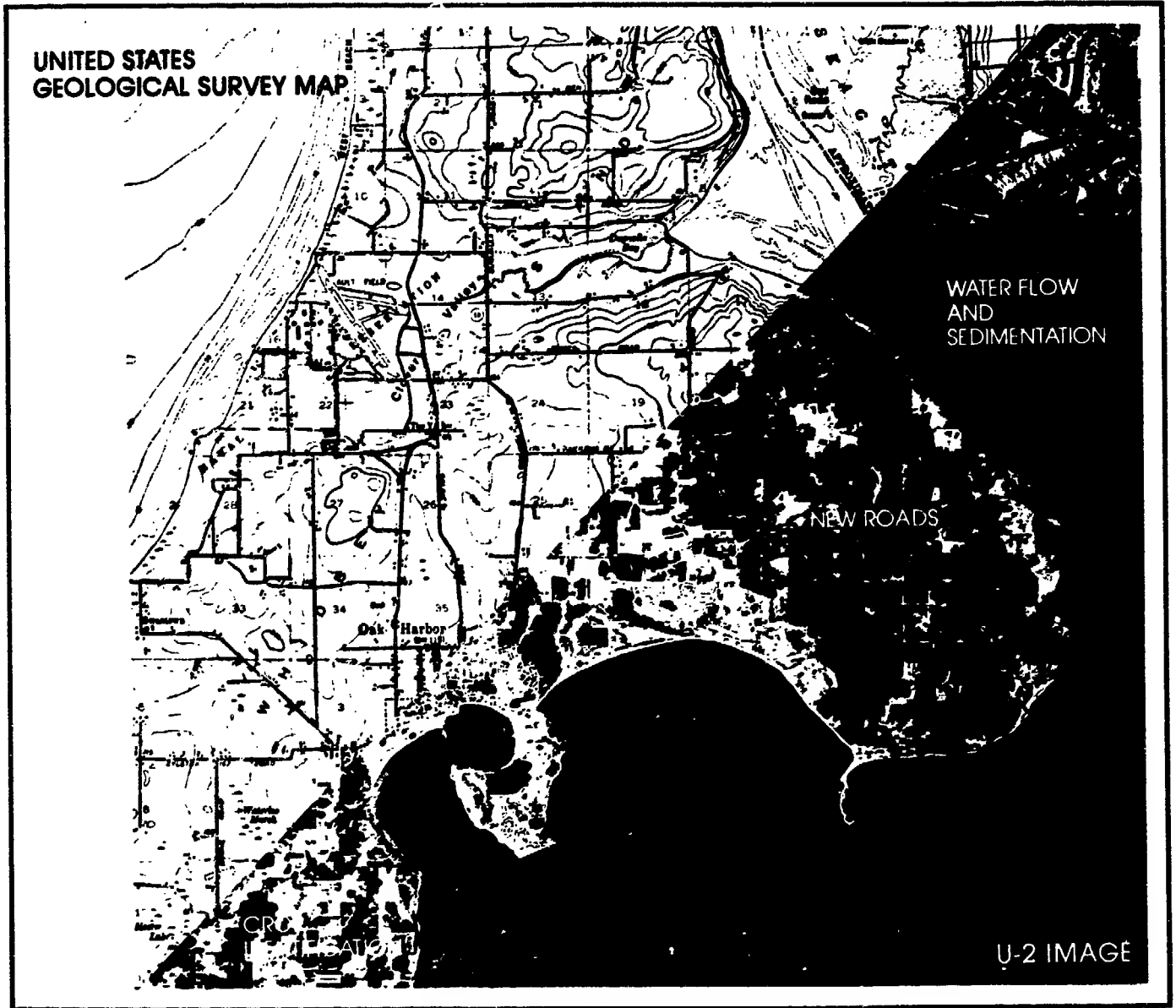
# APPLICATIONS



High-altitude airborne platforms have made major contributions to the scientific data base and have been of value in delineating terrestrial problems and providing a basis for their resolution.

The relatively frequent flight capability of the U-2 (typically 100 flights per year per aircraft) allows good substantiation of data on a seasonal and a geographic basis. Much U-2 activity is presently being devoted to a systematic program of stratospheric air sampling and analysis. These data are being used for many purposes, including the development of stratospheric mathematical models that will provide a better understanding of upper atmospheric transport mechanisms and man's impact on the Earth's protective ozone layer. This research is being conducted in conjunction with NOAA and various academic investigators. Results to date have contributed substantially to baseline measurements of stratospheric constituents. Other scientifically significant results have been achieved in the fields of pollution monitoring, astronomy, and Earth observations.

# PHOTOGRAPHIC SURVEYS



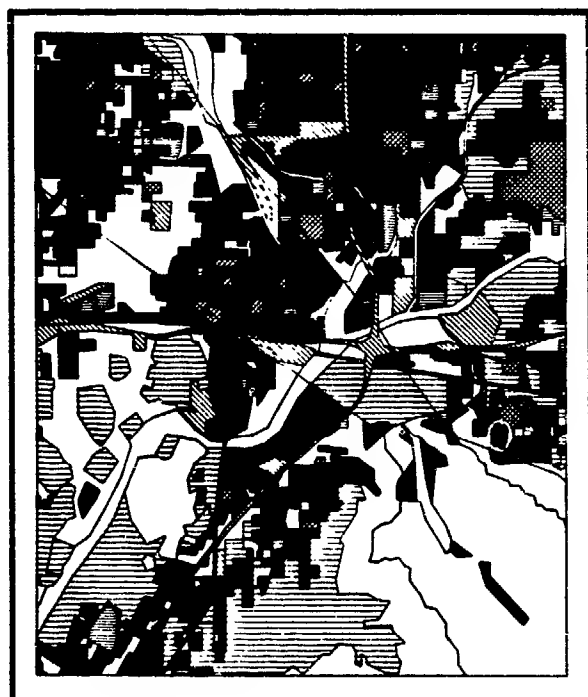
Most mapping procedures rely heavily on aerial photography and aerial photographs have been taken at various altitudes using many kinds of aircraft. Imagery obtained at U-2 altitudes with its large area coverage and minimal distortion, is especially well suited for mapping various kinds of surface features such as vegetation classes, geological features, and snow cover. An indication of the information










content is shown by the photograph on this page of Whidbey Island, north of Seattle, Washington. In this illustration a U.S. Geological Survey map and U-2 image have been placed in register. Such photographs have been used to make original maps, update old maps, and to add additional specialized information such as cropland descriptions and delineations of urban growth.

# LAND USE MAPPING

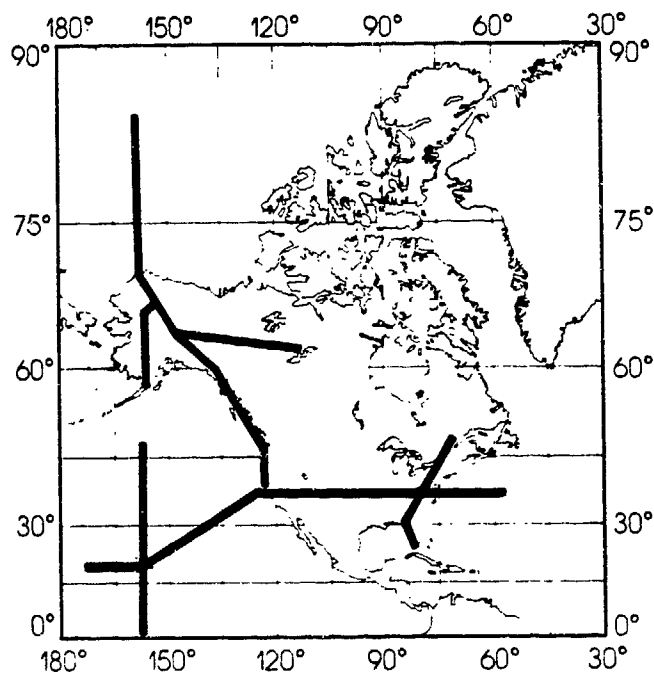


Land use mapping has become an increasingly important tool in managing the utilization and development of our geographic resources. One very important resource that is related to geographic location is water. Where water is scarce, it is important to identify water sources and demands so that water supply and water quality can be maintained. Shown here is an image taken in the Riverside area of California from a U-2 and a corresponding computer-drawn map which has been used to estimate water demands. The map was made by photo-interpreting the aerial imagery, digitizing selected land use classes for computer input, and verifying selected interpretations with ground checks. The computer thus becomes a convenient tool for displaying resource allocation and tabulating statistical information. And once the map is drawn, it can be easily updated to reflect changes in land use.



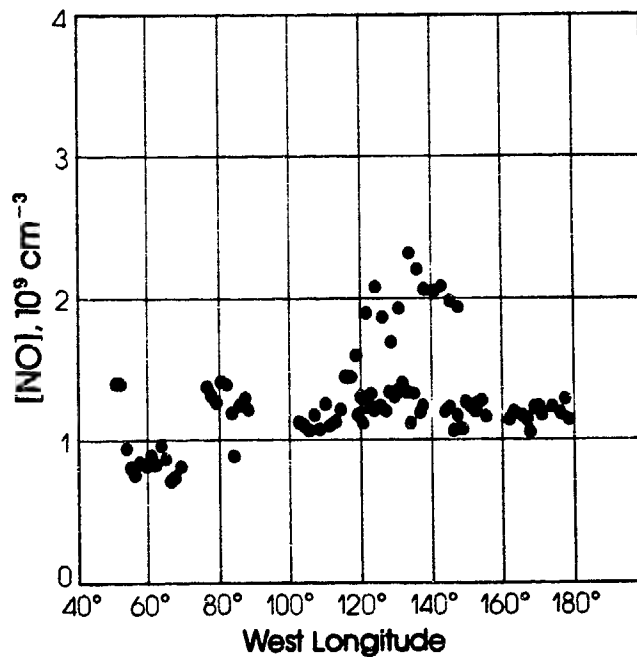
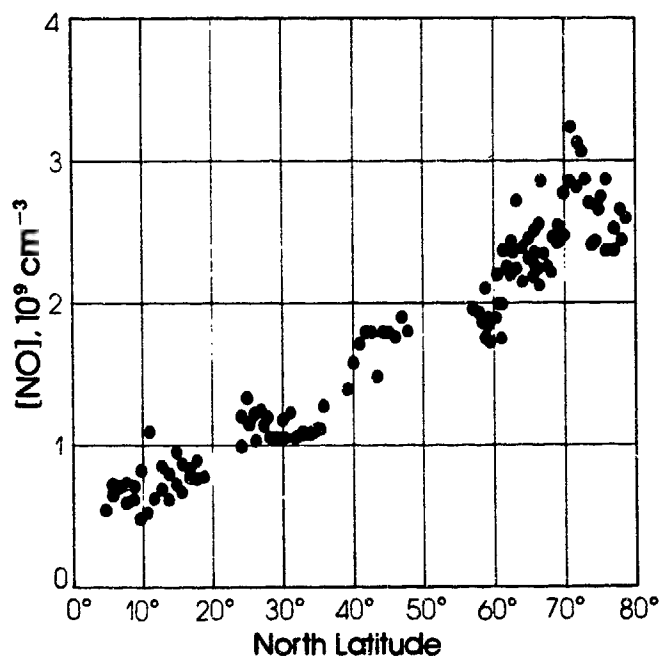
-  Undeveloped
-  Resources
-  Agriculture
-  Recreation
-  Services
-  Commercial Activities
-  Transport & Utilities
-  Industry
-  Living Area

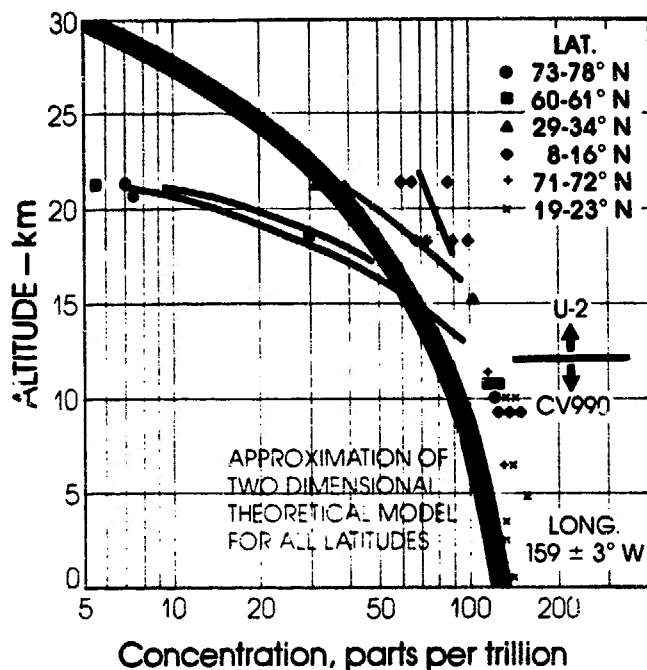
# STRATOSPHERIC SAMPLING



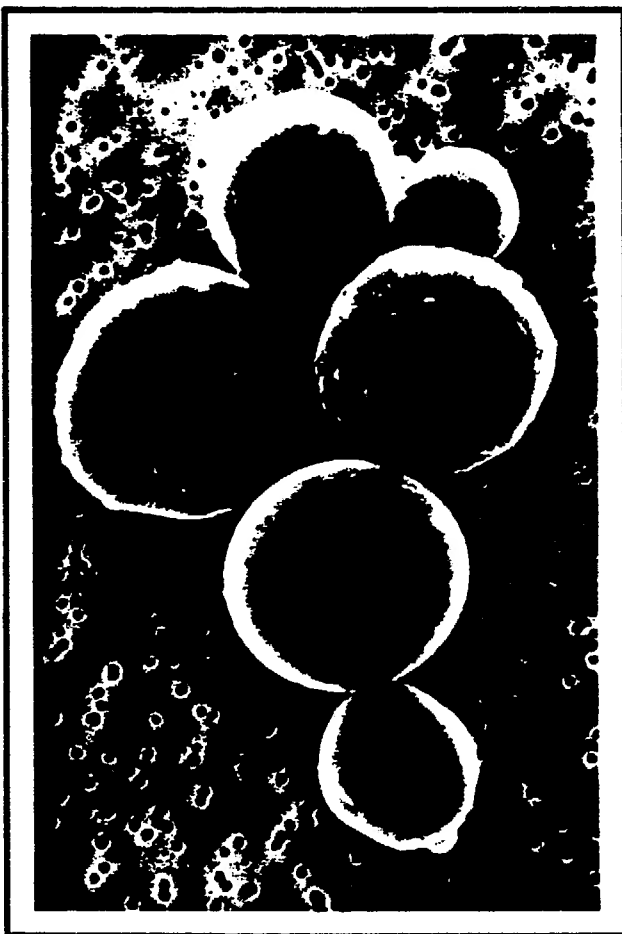
— JUNE  
 — JULY  
 — AUGUST

Global surveys of stratospheric air composition are conducted periodically to help determine the environmental effect of man-caused pollution. Constituent data are being used to construct and validate mathematical models of stratospheric interactions. The adjacent map shows the geographic extent as a function of longitude and latitude over which data are typically collected. The graphs show the concentration of one of the constituents of interest — nitric oxide — as a function of survey cross sections.





Freon and other halocarbon concentrations have been measured at high altitude because of their potential impact on the depletion of the Earth's protective ozone layer. U-2 surveys have revealed halocarbon concentrations that vary as a function of latitude at given altitude—a phenomenon currently being integrated into the theoretical computer models. The accompanying figure shows the measured Freon-11 data and a comparison with the latest two-dimensional stratospheric modeling theory which accounts for mass and species conservation, chemical and solar photolysis, and atmospheric transport. Note that low-altitude data have shown little or no differences in Freon concentration at different latitudes.



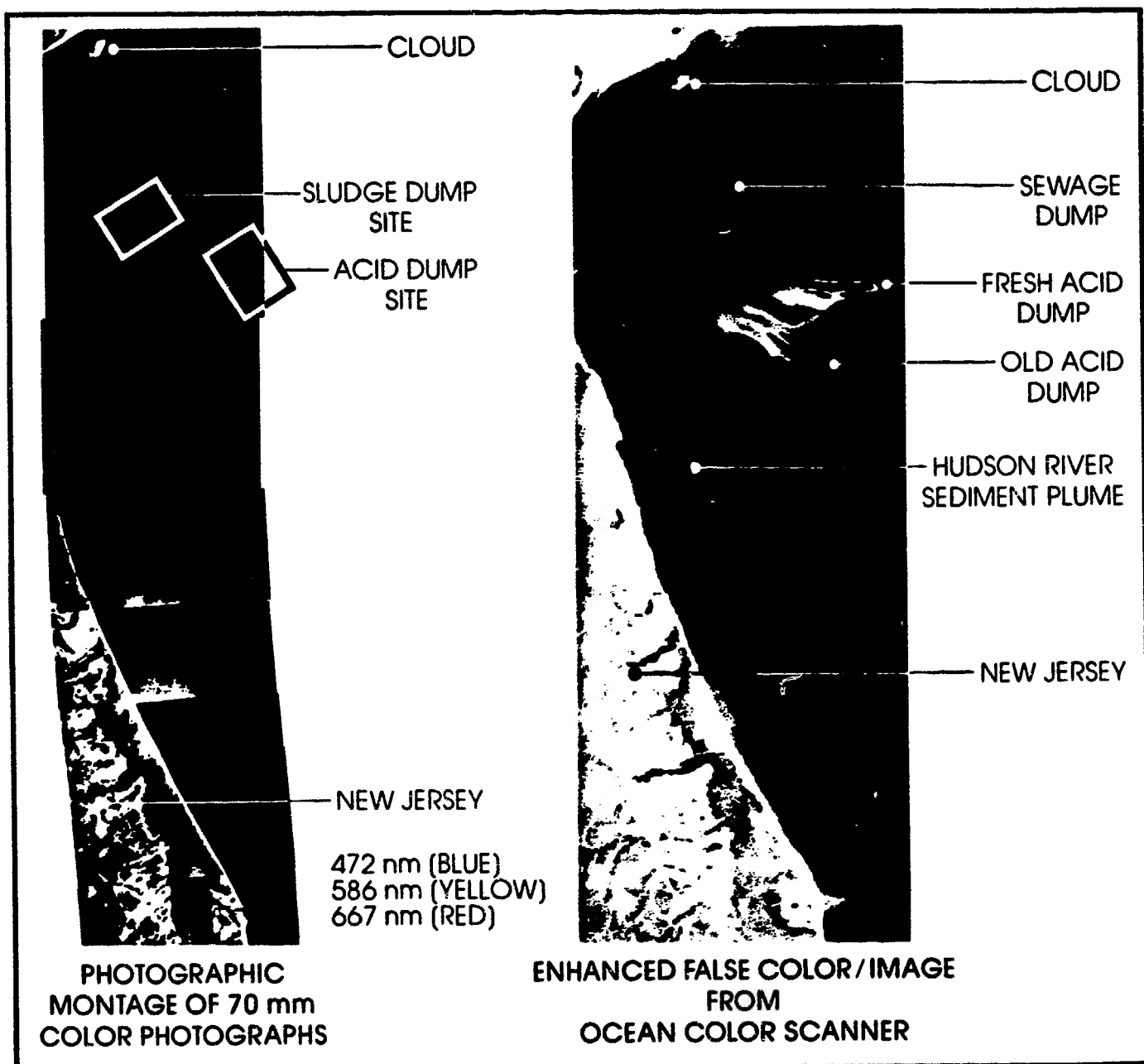
Stratospheric aerosols

Micrometer-sized stratospheric aerosols have been collected with the U-2 by inertial deposition from a 200-m/sec airstream onto thick films of silicon oil. It was discovered that, for the past 6 years at least, aluminum oxide spheres are the major stratospheric particulate in the size range 3 to 8  $\mu\text{m}$ . The most probable source of the spheres is the exhaust from solid-fuel rockets. The photograph shows typical aluminum oxide spheres collected from the atmosphere by the U-2.

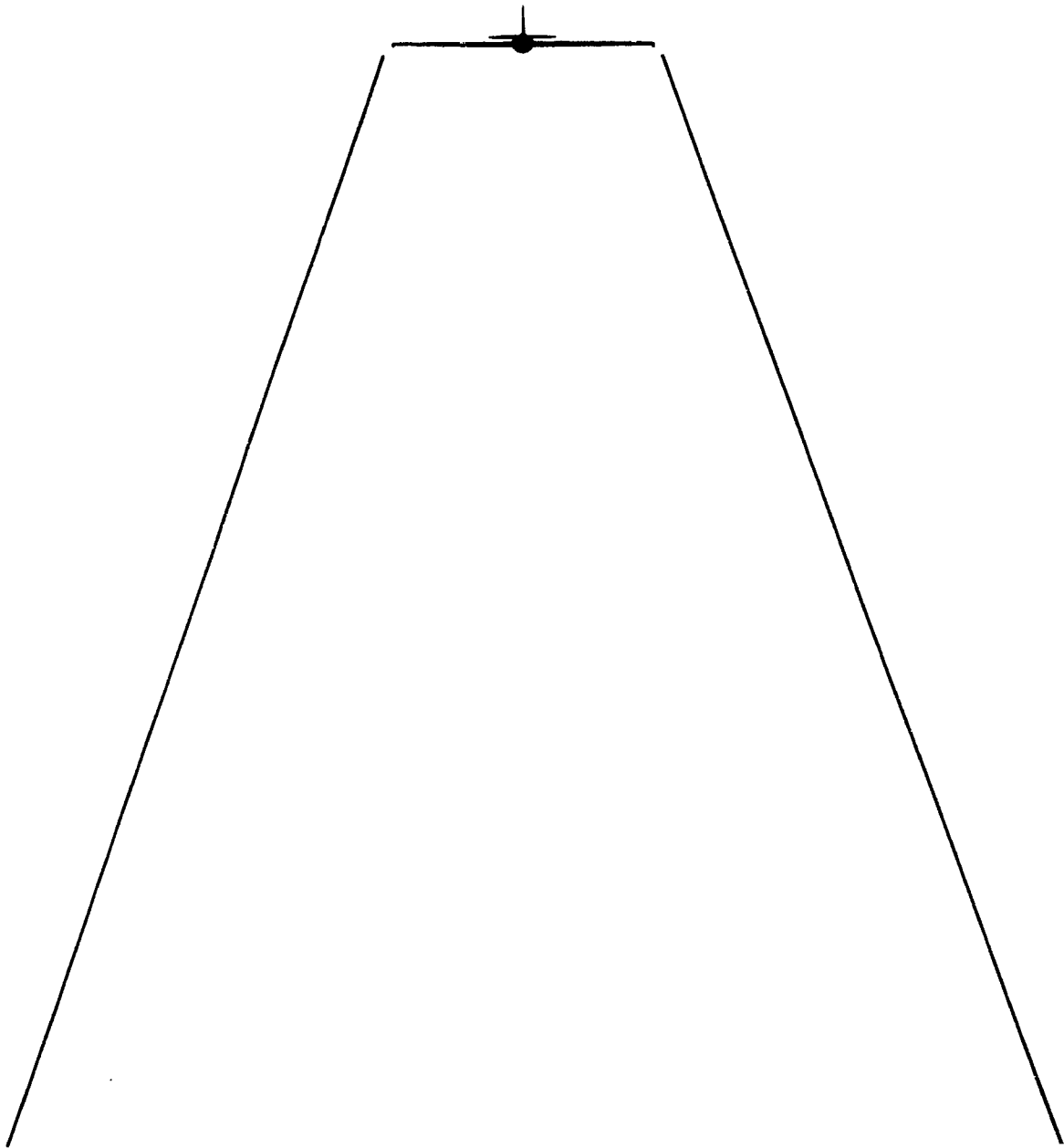
# EARTH OBSERVATION SCANNERS

In preparation for the flight of the Coastal Zone Color Scanner on Nimbus G, the Ocean Color Scanner was constructed for use on the U-2. The scanner has 10 bands ranging in peak wavelengths from 433 to 774 nm. Flights over the

New York Bight have shown sediment plumes and dispersion from dumping areas. Illustrated below are the results of the Ocean Color Scanner shown with conventional 70-mm format photography.



# THE U-2 AND YOU



The NASA Earth survey aircraft offer investigators an opportunity to conduct experiments in flight regimes that would otherwise be impossible.

The Applications Aircraft and Future Programs Office at Ames Research Center is prepared to assist prospective investigators in developing flight-test procedures. U-2 flight support is initiated through a simple flight request system and approval process. This process integrates all aspects of a test program from aircraft scheduling to data processing. Cost estimates for flight and data support will be provided to the investigator as part of the flight request review cycle. When the investigator wants to use his own sensor, studies of aircraft/instrument compatibility will be required, and additional charges for aircraft modification may be necessary.



# FLIGHT SUPPORT

Requests for U-2 flight support should be directed to:

Manager  
Applications Aircraft and  
Future Programs Office (AAFPO)  
Mail Stop 240-5  
Ames Research Center  
Moffett Field, California 94035  
(415) 965-6092

The Applications Aircraft and Future Programs Office will start review procedures and determination of costs associated with proposed U-2 flight support programs. Actual costs are a function of data product, resolution, area covered, payload sharing, and a number of other factors.

The cost of operating the U-2 often exceeds the operating expenses of other aircraft because of its high-altitude performance and the correspondingly strict standards imposed on its maintenance and operation. Consequently, use of the U-2 is of economic advantage only when a need exists for high-altitude capability, good platform stability, or long range. These aircraft characteristics are required, for example, in such applications as stratospheric sampling, when large-area coverage is required in a single frame of imagery, or where coverage is required over extended distances.

The review and operational process for users of NASA's U-2 aircraft and data-handling facilities at Ames Research Center is illustrated.

